FINAL PROJECT:

Robotic Whack-A-Mole

Congratulations! You've been selected to participate in the prestigious Purdue Robotic Whack-A-Mole competition. The only problem is that, per the competition name, only robots are allowed to participate. So now you have to build and program an autonomous robot in time for the competition.

Note: Read through this whole document and make sure you understand the robot requirements before starting the brainstorming/design process.

A. Robot Physical and Cost Constraints

- Actions of the robot on the playing field must be autonomous: no human interventions and no tethers. You are only allowed to interact with your robot in between competition attempts.
- Your robot must start within the 24 in. x 24 in. home square on the playing field with an initial volume of 12 in. x 12 in. x 12 in. (see Task Description and Robot Description below).
- Your item distribution system (the Mole-Whacker) must be home made. You may use either a custom built chassis or a purchased one.
- Total cost of each robot is to be less than $400. The course budget provides up to$200 per team and the team members may contribute additional parts up to $200 in value. Current market value is to be used in determining the cost/value of contributed items and not your personal acquisition cost. (All components purchased with university funds remain the property of the University.)

B. Whack-A-Mole Game

In a game of Robotic Whack-A-Mole, you will be placing Mole-Whackers (foam balls or cubes) on squares with Moles. The squares that Moles are occupying will be identified by color, with the field having 3 different color squares (not including the starting square which will be white). At the start of each game, a TA will tell you the color of the squares where Moles are hiding. Your robot must then autonomously search the playing field for the Moles and place Mole-Whackers on those squares.

B.1. Playing Field

The playing field is a square plywood surface (8 ft. x 8 ft.) that has been separated into 16 equal sized squares. Side rails which are made of white foam board will be placed around the perimeter of the field to prevent robots from rolling off the field, shown as bold solid gray lines in Fig. 1. These rails extend vertically upwards 6 inches beyond the plywood surface, but may not be perfectly perpendicular to horizontal plywood surface. The playing field is divided into colored squares that are 2 ft. x 2 ft by black lines. These lines are physically created by using 3/4 inches width *black electrical tape*. The starting square is white, while the remaining 15 squares are red, green, or blue, with 5 of each color. Detailed dimensions of the playing field are shown in Fig. 1. The color distribution shown may not be the final one for the competition.

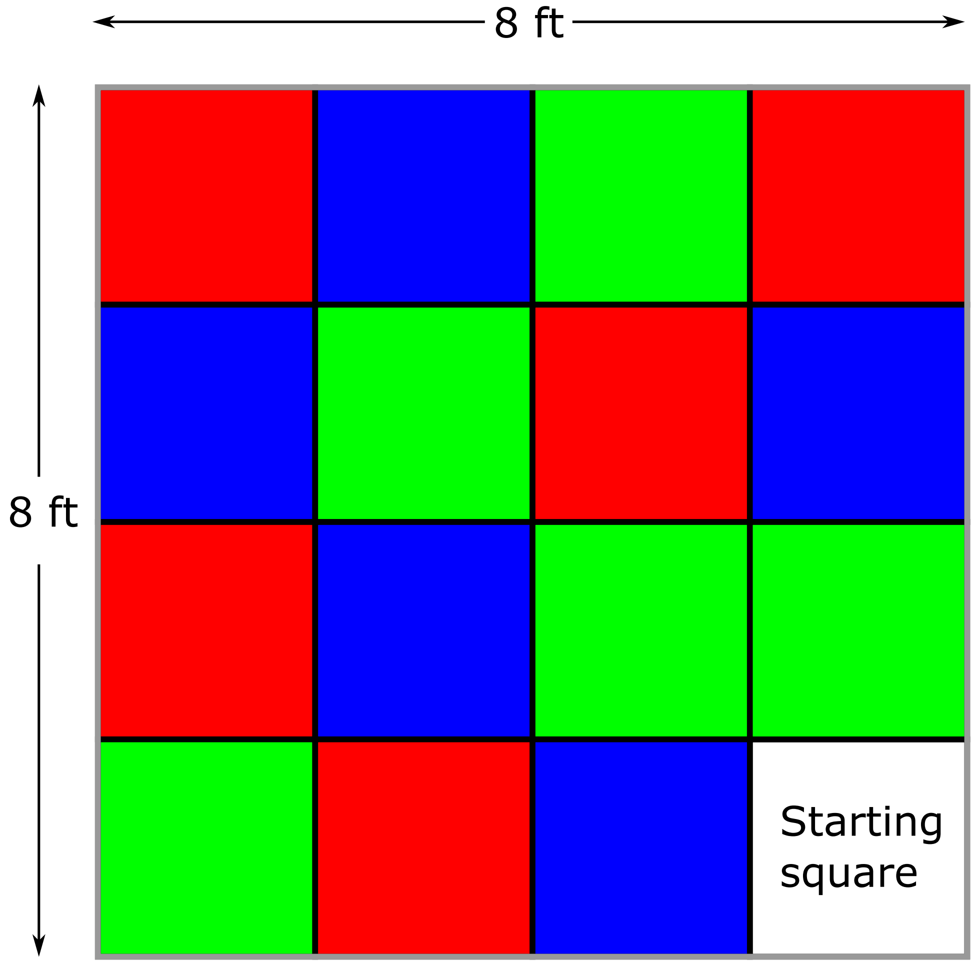

Figure 1: Top view of the playing field

B.2. Mole-Whackers

Mole-Whackers are foam balls or cubes. Your team may use either balls or cubes or both. The foam balls are 2.5" in diameter. The foam cubes have a side length of 3/4". Each team will be given 4 Mole-Whackers of their choice for practice and testing. You are not allowed to modify your Mole-Whackers and new Mole-Whackers may be used during competition at the discretion of the TAs.

B.3. Game Description

1. You will load the Mole-Whackers into your robot and load and start your code before the game begins.
2. You will place your robot within the starting square. You may place it anywhere, at any orientation, within the square to start.
3. The TA will then tell you the color of the squares where Moles are located. You will set this color into your robot using an input. **Note: you cannot change your code after you place your robot.**
4. You will press a button (or other input) to tell your robot to start the game, which will also be the start of the game time.
5. Your robot will navigate the field and place Mole-Whackers on squares with Moles. **Mole-Whackers must stay on the square at the end of the round to count.**
6. The round will end after 2 minutes or after your robot returns to the starting square and stops moving. If the round lasts 2 minutes, your robot must stop moving at the end of time.
7. Points will be scored for placement of Mole-Whackers (see Scoring).

B.4. Competition Scoring

Scoring will be made as a combination of the correctly placed Mole-Whackers and the incorrectly placed Mole-Whackers **at the end of the round**. Time will be used as a tie-breaker in the case of ties. If more than one Mole-Whacker is placed on the same square, only one will be counted. Mole-Whackers placed in the starting square will always be judged incorrect.

Correctly placed Mole-Whackers are worth 2 points.

Incorrectly placed Mole-Whackers are worth -1 points.

Mole-Whackers placed on the boundary between squares will be adjudicated by the TAs for which square they are occupying.

C. Robot Description

C.1. Required Functions

In addition to any functions your team deems necessary to play the above game your robot is required to have the below function:

- Your robot must have some input to set the color for the Mole squares in a given run. This input can be analog or digital.
- Your robot must have some input to indicate to it that a round has started. This input must be digital. You **cannot** use the reset button on the Arduino to accomplish this function.
- Your robot must have an emergency stop switch easily accessible on the surface of the robot that will stop actuator movement of the robot.
- Your robot must have visual indicators that show: (1) the selected target color for Mole squares, (2) whether the robot has entered game mode once the start button is pushed, and (3) one other feature of the robot's operation (for example number of Mole-Whackers left, color of current square, current score, etc.). Examples include LEDs, seven-segment displays, servos, but feel

free to get creative with your visual indicators
- Your robot must have at least two sensing modalities. Sensors have be used to sense internal or external information but are separate from the color setting and start inputs described above. If you believe that you have a robot design using only 1 sensing modality, please consult with the instructor and/or TAs.

C.2. Robot Rules

- Robots must initially fit within a 12 in. x 12 in. x 12 in. cube. They may expand outside this size after the round starts, but must return to the 12 in. x 12 in. x 12 in. cube size by the end of the round.
- At the home position, one team member may briefly contact with the robot to initiate autonomous operation, such as push a button, or flip a switch. Thereafter, the robot must operate entirely on its own. If robot movement does not commence within 30 seconds after the start of the match, the team then forfeits the match, i.e. receives 0 score for the match. “Robot movement” includes any visible change in location, appearance, or configuration of the robot.
- During each match, the robots are limited to operate within the bounds of the playing field.
- The robot must stay in contact with the plywood surface at all times. Hovering or flying, although impressive, is not permitted.
- No part of the robot, except the Mole-Whackers, may become ballistic during operation. Mole-Whackers may not be thrown or launched over the edge of the playing field.
- Within the limit of the starting robot size (12 in x 12 in x 12 in), there is no limit on the number of Mole-Whackers a robot can carry. However, all Mole-Whackers used must be contained within the robot at the start.
- Robots must not affect the color, texture, moisture content, or friction coefficient of the playing field.
- Robots can not damage or in anyway puncture or modify the shape or color of the foam balls and cubes (Mole-Whackers).
- The robot operation must be terminated at the end of the match. All objects in motion at the end of the round will be allowed to stop motion naturally.
- It is the team’s responsibility to ensure that all robot functions and electronics work properly during each round.
- The instruction team (instructor and TA) may add, delete or alter rules at anytime, as they see fit, in an attempt to ensure a safe, fair and enjoyable game. Any violation to the above rules and regulations will be subject to disqualification.

D. Deliverables

D.1. Interim Progress Check-Offs

Each project team is responsible for making three presentations about the progress of their final project during the second half of the semester. These presentations will take place during scheduled lab or lecture hour, in accordance with a schedule to be posted on the Brightspace course website.

Each team member will be responsible for at least one part of your team’s presentations. After the oral presentation, the team will be asked to field questions from the audience. The interim progress reports will be given by Powerpoint (or other slideshow) presentation and limited to 8 slides. A Powerpoint for interim reports can be found on the Brightspace course website. You are free to customize the provided template. Each presentation should include, 1) an “introductory” slide with team information and each member’s responsibility, 2) a "status" slide with current progress and constraints, and 3) a "future" slide that highlights changes your team will be making as the project moves forward. The remaining slides should focus on the following topics for each check-off:

Week 8 (3/1-3/3) Design Check-off: Limited to 12 minutes. Provide details of your design, making sure to include details on how you plan to meet each of required functionalities. **(Note this is the only check-off that will take place during lab meetings instead of lecture time.)** We highly encourage everyone to attend your lab time for this checkoff, to share ideas and be available to provide feedback to your classmates.

Week 11 (3/22 and 3/24) Circuit Design and FSM Check-off: Limited to 12 minutes. You must show circuit designs for the major functionality of your system. And you must show a video or screen shot of a prototype finite state machine in code. Since you may not have circuitry ready at this point, your FSM can be demonstrated purely though inputs and outputs to the serial monitor.

Week 13 (4/5 and 4/7) Subsystem Function Check-off: Limited to 12 minutes. You must show functioning or all major subsystems of your system. These subsystems do not need to be integrated or demonstrated on the robot. Subsystems to show include: movement of robot chassis (or other equivalent subsystem), Mole-Whacker distribution subsystem, sensor modalities (may be included in other subsystems as relevant), and robot state display.

You are encouraged to work with your team to ensure that all team members make presentations that are complete, concise, and well-planned. It is up to you and your team to decide the order in which each of you will make the interim presentation. It is not necessary that you attend a presentation period if you are not delivering an interim report. However, you may wish to show up to see what problems other teams have encountered, ask questions of teams that have solved problems that you are currently facing, and to support your teammates in making strong presentations.

A detailed report schedule will be posted on Brightspace later. **Slides need to be submitted to Gradescope for evaluation after the presentation.**

D.2. Final Check-Off

You will be required to show full functionality of your robot before the competition, during lecture time or lab time on Thursday, April 28th. To receive full points, you must demonstrate that your robot can play the Whack-A-Mole game per the above rules and place at least one Mole-Whacker correctly. If your robot places any Mole-Whackers incorrectly, they will be required to place additional correct Mole-Whackers. You will be given two attempts to check-off in a row, after which you must let other teams attempt before attempting to check-off again. Final check-off will be done with the TAs and they will judge if the requirements are met.

D.3. Final Report

The final report should be concisely written and free of grammar errors. The report is limited to 10 pages with figures/plots, excluding appendices. A penalty will be applied for extra pages. The final project grade will consider both the final report and the competition. You are writing for two audiences: 1) readers who want to find out if your solution will solve a similar problem; and 2) readers who want to reproduce what you have done. The report should be in a standard engineering report format, including:

- Cover page-team name and members' name, date of report.
- Title-should be descriptive (and short!).
- Abstract-capsule description of what's in the report, limited to 200 words (In many cases the title and abstract are published without the rest of the report, so they need to stand on their own.).
- Introduction-project objectives, and briefly introduce how you come to the solution method, including robot design, motion planning, sensor and actuator choice, calibration, control strategy, etc.
- Body-Detail robot design, motion planning, sensor and actuator calibration, and control strategy (if applicable) by sections. Must describe how all required functionality of the robot were achieved.
- Results-description of experiments or testings done and data obtained. Can also be a description of redesign process.
- Discussion-relate the results to the objectives, and include one or two examples describing what constraints you encountered and how you solved these.
- Conclusion-succinct statement of what was accomplished and what to do next.
- Appendices-relevant material not needed by the average reader. This is a good place to put detailed schematics or full code.

One team member needs to submit the final report with codes and drawings through Brightspace by **5 pm (EST) on Monday, May 2nd.**

D.4. Code

One team member needs to submit the final Arduino code or any implemented code in an electronic format through Brightspace by **5 pm (EST) on Monday, May 2nd,** including all library files and all necessary code files. Code should be clearly commented! Compress code into a single ZIP file prior to submission.

D.5. Drawings

Final CAD drawings and circuit diagrams are to be submitted in an electronic format through Brightspace by **5 pm (EST) on Monday, May 2nd**. You may use EAGLE, Fritzing for circuit drawing and SolidWorks, UG for CAD drawing. The drawings should be clear enough for another person to recreate your work. Compress drawings into a single ZIP file prior to submission.

D.6. Physical Electronic Parts

Return electronic parts which were purchased with the university fund to ME 588 lab area at **2:30 - 5:00 pm (EST) on Monday, May 2nd**.

E. Purchasing

- University-funded purchases should be requested through the TA. Please refer to the purchase instructions provided on Brightspace.
- Please consider shipping times!Many suppliers may take weeks (or even months) to deliver parts, especially if the component is not currently in stock or the supplier is not at U.S.
- Be aware that the ongoing COVID-19 coronavirus outbreak may have a serious impact on the availability of electronic and other components.
- Personal purchases can be made at brick-and-mortar stores, as well as online stores.
- Personal purchases WILL NOT be reimbursed.
- It is recommended you do not use university funds to purchase batteries.(You are required to turn in materials purchased by the university fund at the end of the semester, and a battery that sits in the parts cabinet for a full year, until next year's course, is generally worthless to anyone. Better that you keep the battery in case you have an opportunity to use it.)
- There are left overs from past semesters. You may trade these components with the course budget. Details will be posted later.

F. Working Area

POTR B016:

- Teams can meet in POTR B016 only at the scheduled lab time and when the TA on duty is present.

Machine Shop, Malott Prototyping Suite:

- Please refer to the Project Facility Access Guide on Brightspace for accessing these facilities.

G. Advice

- Do not wait! Start early! Start now!
- Search the web for components, circuit ideas, and sensors (look for robotic sites).
- Don't reinvent the wheel. Your time is quite limited, so look for concepts and methods that have proven themselves to be reliable.
- Try to limit the number of sensors and actuators. More sensors and more actuators translate to more states in your state machine.
- Try to leverage (use already made) mechanical components as much as possible. You might want to check the Purdue University Warehouse and Surplus Store (Purdue Salvage).
- There are many ways to sense and locate the field and your robot. A few minutes of research/planning in the beginning could save you days of work. There are lots of how-to and detail description of subsystems on Youtube and other websites that you can leverage and use.
- Prototype any subsystem you are unsure about. Better to fail early when you have time to recover, than to discover a problem in the final weeks of the semester.

- Make sure you account for robot weight and traction. The most common mistake in previous semesters is that a vehicle does not have enough torque or traction to drive the device!
- Check the sensors that you will be using. Read the datasheet carefully. Make sure you know how they work and how to interface with them! The manufacturers' application notes usually have example circuits for interfacing with the sensors and actuators.
- Beware of grounding, noise, floating inputs, and impedance mismatch type bugs! If you don't know what these mean, look them up in the notes and/or ask questions!
- Think about debugging when you build your circuits. Strategic use of connectors, testpins, LEDs, or external displays can save significant debugging time and agony.
- Don't let your circuity become a rat's nest of wires. Troubleshooting becomes very difficult when you're guessing about which wire does what, or you're unsure whether your connections are still secure.
- Once you have tested your prototype circuit, you will need to build it on a prototype board and solder the components. THIS TAKES TIME! It is best to make use of the dip sockets so that if a component fails, you can change it with minimum rework.
- The lab has a Dremel tool for small part modification. We also have a few soldering stations.